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SHORT COMMUNICATION

A Three-Camera Multispectral Digital Video Imaging System

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This article describes a multispectral digital video imaging system for remote sensing research. The system is comprised of three charge coupled device (CCD) analog video cameras, a computer equipped with an image digitizing board, a color encoder, and super (S)-VHS portable recorder. The cameras are visible/near-infrared (NIR) (0.4–1.1 μm) light sensitive. Two of the cameras are equipped with visible yellow-green (YG, 0.555–0.565 μm) and red (R, 0.625–0.635 μm) filters, respectively, while the third camera has a NIR (0.845–0.857 μm) filter. The computer is a 486-DX50 system that has an RGB image grabbing board (640 × 480 pixel resolution). The NIR, R, and YG image signals from the cameras are subjected to RGB inputs of the computer digitizing board, thus giving a color-infrared (CIR) composite digital image similar in color tonal rendition to that of CIR film. The hard disk can store 1000 CIR composite images. In addition, the cameras' signals are also subjected to a color encoder that provides an analog CIR composite which is stored on the S-VHS recorder. The analog CIR imagery recording serves as a back-up in the event the computer malfunctions. A global positioning system (GPS) is also integrated with the imagery. The system provides high quality digital video imagery that is superior in resolution to analog video imagery. Image examples are given demonstrating its application to natural resource assessment.

INTRODUCTION

Within the past few years interest in the application of video imaging equipment for remote sensing has greatly increased (Escobar et al., 1983; Vlcek, 1983; Meisner and Lindstrom, 1985; Nixon et al., 1985; 1987; Everitt et al., 1986; 1991; King and Vlcek, 1990; Mausel et al., 1992). The principal motivator for using video is the near-instant availability of the imagery for visual assessment. Other prominent characteristics that make video attractive for remote sensing are its immediate potential for digital processing of the electronic signal and its higher light sensitivity than film cameras, which permits imaging in narrow spectral bands and gives sensitivity further into the infrared spectrum than film cameras (Nixon et al., 1985; Everitt et al., 1986). Video equipment is also inexpensive, portable, and easy to use.

Recent advancements in videographic and computer technology have resulted in the development of digital imaging systems. King (1992) evaluated a single black-and-white (B&W) digital frame camera for remote sensing applications. The system was equipped with a rotating filter wheel which housed user-selectable narrowband interference filters and a PC with a high resolution frame grabber, a high capacity buffer, and a large hard drive. This system delivered high quality multispectral imagery that was superior in quality to VHS video imagery and approached that of photographic products. Pearson et al. (1994) assembled a multispectral three-camera fully digital aerial imaging system for monitoring agricultural crops. The system was comprised of three CCD cameras equipped with narrowband filters that were integrated with a computer for storing high quality imagery. Data were used for a variety of applications including detecting insect infesta-

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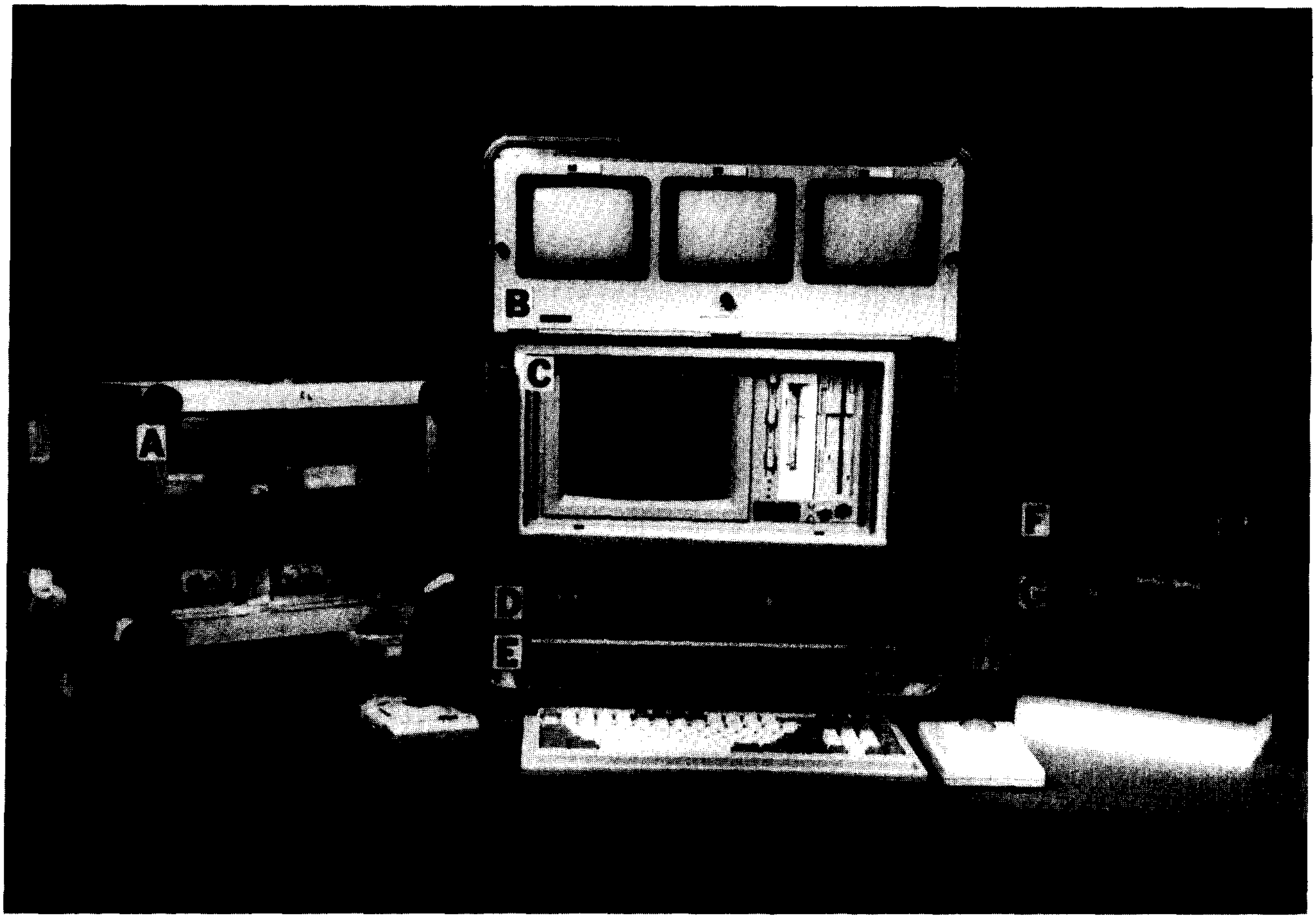

Figure 1. The three-camera multispectral digital imaging system. The system is comprised of three CCD analog cameras (A), a rack mount with three 12.5-cm B&W monitors (B), a computer with built-in monitor and image grabbing board (C), a power distributor (D), a color encoder (E), a global positioning system (F), a 1.25-cm format super-VHS recorder (G), and an interphaser (H).

tions, hail damage, irrigation problems, and inconsistent fertilizer applications in crops.

Benkelman and Behrendt (1992) and Honey (1993) developed four-camera digital imaging systems utilizing CCD video cameras integrated with a computer. Both systems utilize user-selectable narrowband filters, giving them multispectral capabilities. Although these systems incorporated video cameras rather than true digital cameras, they provided high resolution imagery that could be used to discriminate individual plant and vegetation types and assess vegetation condition.

This article describes a three-camera multispectral digital video / computer airborne imaging system for remote sensing studies.

SYSTEM DESCRIPTION

Figure 1 shows the video / computer aerial imaging system. The system is comprised of three CCD analog cameras (A), a rack mount with three 12.5 cm B&W monitors (B), a computer with built-in monitor and image grabbing board (C), a power distributor (D), a color encoder (E), a global positioning system (F), 1.25 cm format Super (S)-VHS recorder (G), and an interphaser (H). The B&W cameras (Cohu[1] Model 4800 series) are mounted on a lightweight aluminum frame that permits image acquisition from ground level and / or aircraft. The cameras are visible / NIR light sensitive (0.4–1.1 μm) that have better than 550 horizontal lines resolution. Each camera is equipped with a synchronized generator-lock connector that allows any camera to be the master camera to sync / genlock other cameras. This permits the acquisition of continuously synchronized imagery. These cameras have 12.5 mm focal length fixed lenses and are also equipped with narrowband (8.5–12.6 nm band widths) interference filters. One camera has a NIR (0.845–0.857 μm) filter, one has a R (0.625–0.635 μm) filter, and the other camera a YG (0.555–0.565 μm)

[1]Trade names are included for the benefit of the reader and do not imply an endorsement of or a preference for the product listed by the U.S. Department of Agriculture.

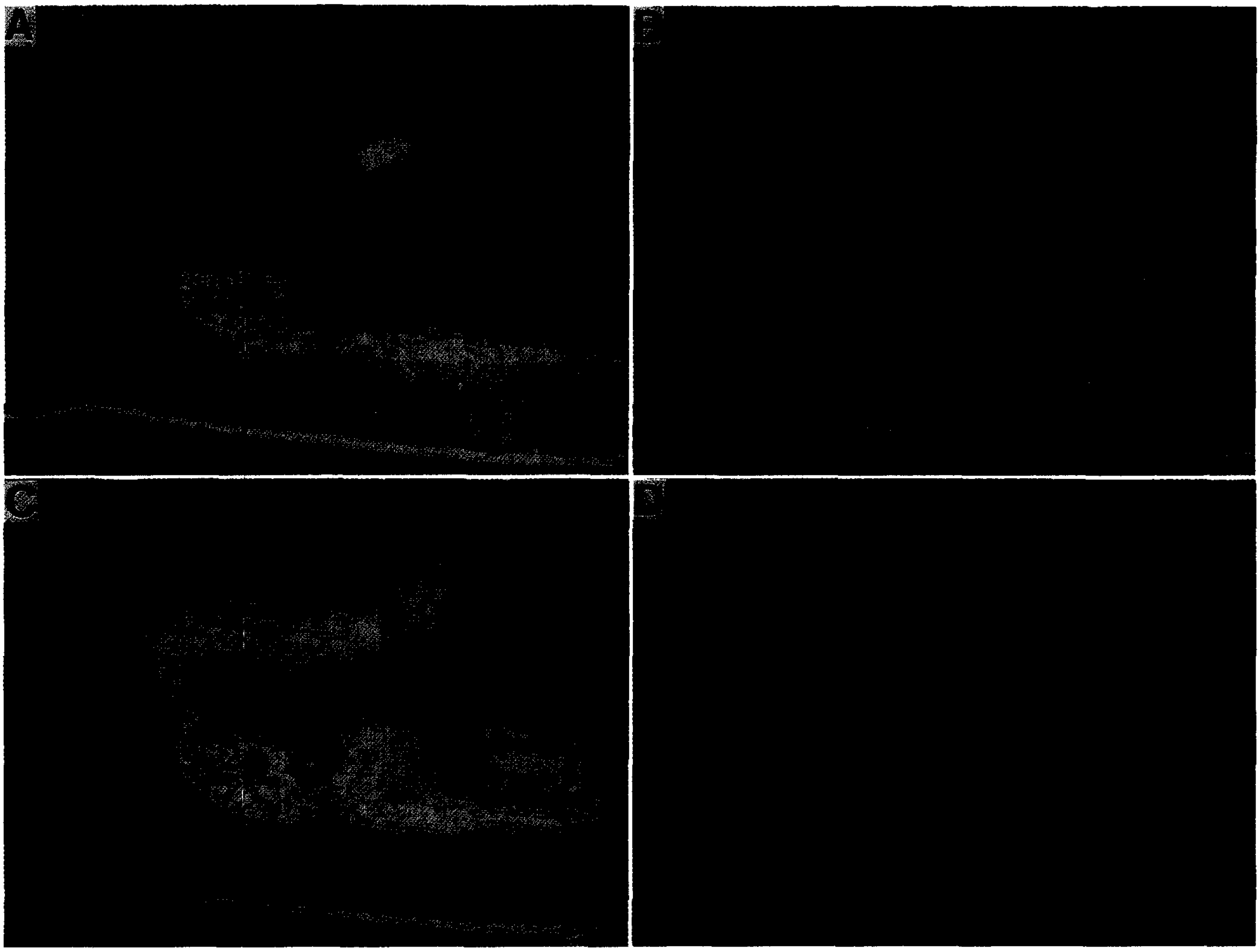

Figure 2. Examples of digital video narrowband black-and-white images of the yellow-green (A), red (B), and near-infrared (C) bands, and a color-infrared (CIR) composite (D), of a rangeland area near Sinton, Texas. The arrow on the CIR image points to the pinkish image tone of silverleaf sunflower. The GPS data appears on the bottom of the red and CIR images.

filter. The alignment of these cameras to acquire real-time registered CIR imagery has been previously described by Everitt et al. (1991).

The computer is a Bi-Link 486 DX50 system that has a 22.5-cm built-in S-VGA color monitor. It is equipped with a Matrox Magic RGB image grabbing board having 640 × 480 pixels resolution. The computer has a 1000 MB storage capacity hard drive and a rewritable magneto optical drive. Each RGB image occupies approximately 0.95 MB on the hard drive. A "joystick" was added to the computer to serve as a capturing trigger device rather than the use of a keyboard. The NIR, R, and YG image signals from the cameras are subjected to the RGB inputs, respectively, of the Magic board in the computer and also to the RGB inputs, respectively, of the FORA (Model ENC-110) color encoder. This permits the simultaneous acquisition of both digital and analog real-time CIR composite imagery. The digital imagery is stored on the computer hard drive, while the analog imagery is recorded on the Panasonic (Model AG-7400) S-VHS recorder. The hard drive can store 1000 CIR composite images. The analog CIR recorded imagery is obtained in the event the computer malfunctions on an ongoing mission.

During image acquisition, the CIR composite imagery is viewed on the computer built-in monitor, while the B&W imagery is viewed on the three-rack mounted Panasonic (Model WM-5203B) B&W monitors. Prior to digitizing and recording imagery, the B&W imagery is displayed on the monitors to assist in the adjustment of the camera apertures for best contrast in each band image and for color balance of the generated composite image. Also, image scenes being digitally acquired are readily viewed to ensure the area of interest is correctly obtained.

The GPS integrated with this system is a Trimble Transpack II navigation receiver. The navigation system constantly receives data from GPS satellites and readily calculates and displays continuously the flight direction (bearing), altitude, time, ground speed, and latitude /

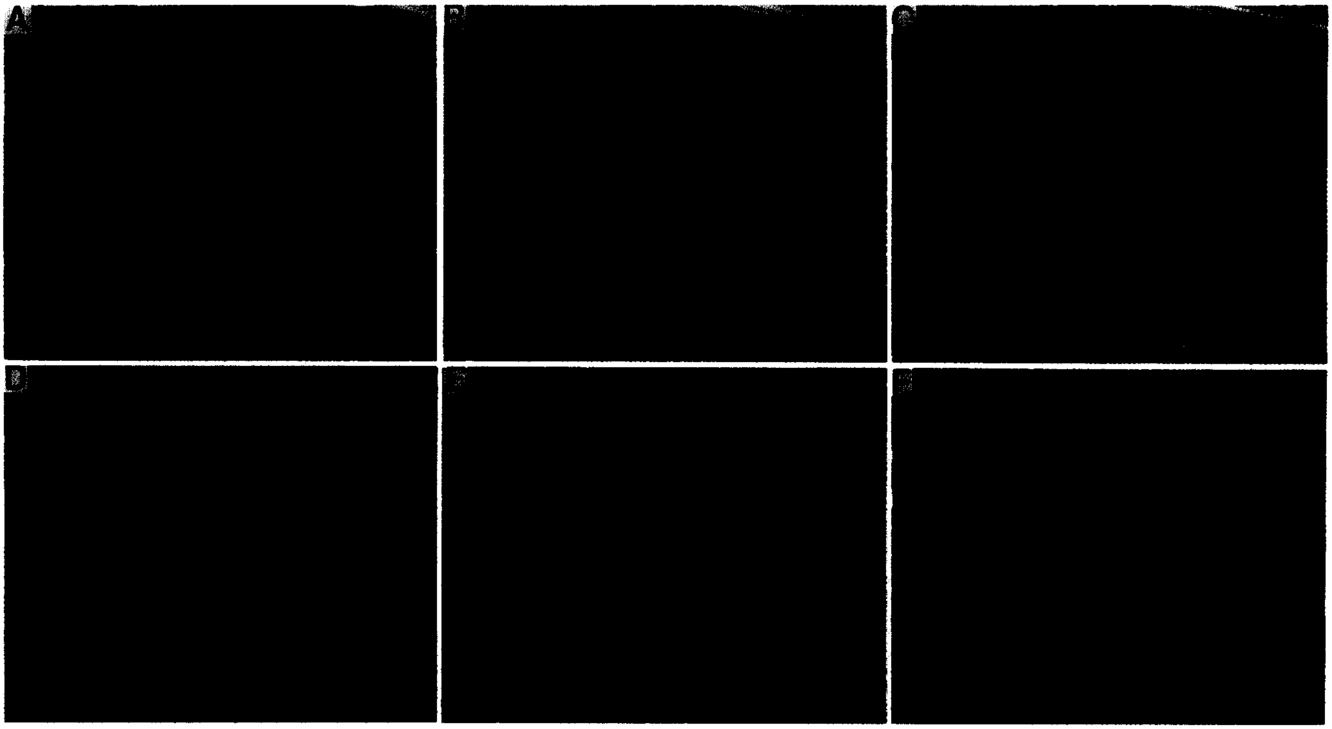

Figure 3. Color-infrared analog video (A), digital video (B), and photographic (C) images of a peanut field near Pleasanton, Texas. The three lower images (D, E, and F) show 10 × enlargements of the center of each of upper three respective images.

longitude coordinates. The Compix interphaser (Model LP-701) transfers the continuous GPS information on the last two lines of the R-filtered camera, which in turn is also superimposed on both digital and analog composite images. The latitude / longitude coordinates correspond to the approximate center of each image. The addition of the GPS facilitates the integration of imagery into a geographic information system (GIS).

The power source for this system is provided by the aircraft's 24-V battery. The power for the cameras, recorder, GPS, and interphaser is rendered by means of a converter that reduces 24 V to 12 V dc, whereas the computer and monitors are powered by means of an inverter that changes 24 V dc to 110 ac.

The cost of the system, as shown in Figure 1, is approximately $29,000. However, this includes the color encoder, S-VHS recorder, GPS, and interphaser, which are optional to the digital video system per se. The basic system, which is comprised of the three cameras and mount, computer, rackmount with three B&W monitors, and power distributor, can be assembled for about $18,000.

Imagery was obtained of various agricultural (1,060 m alt.) and rangeland (600 m alt.) sites with a fixed-wing aircraft. Color-infrared photographic imagery was acquired simultaneously with some of the analog and digital video imagery to qualitatively compare the resolution among the three types of imagery. Photographic imagery was obtained with a Hasselblad 70 mm camera with an 80 mm lens. The Hasselblad camera contained Kodak 2443 film and employed a Hasselblad No. 12 orange filter. Video images presented here were photographed from an image display monitor.

IMAGE EXAMPLES

Figures 2A, 2B, 2C, and 2D show digital video narrow band B&W images of the YG, R, and NIR bands and a CIR composite, respectively, provided by the three-camera system of a rangeland area near Sinton, Texas. The GPS data appears at the bottom of the R and CIR images. The image pixel resolution of this scene is 0.66 m. The arrow on the CIR image points to the pinkish image tone of silverleaf sunflower (*Helianthus argophyllus* Torr. and Gray). Mixtures of green herbaceous plant species have various red to magenta tones, woody plant species have a red tone, the shrub spiny aster (*Aster spinosus* Benth.) has a reddish-brown image response, and dormant herbaceous species / sparsely vegetated areas have gray to light gray tones. A small pond is located in the center of the image. The pink image response of silverleaf sunflower was primarily attributed to white pubescence (hairs) on the leaves and stems which caused high visible reflectance (Gausman et al., 1977). Silverleaf sunflower can also be detected in the YG narrowband image, where it has a whitish-gray tone, which agrees with the spectroradiometric reflectance data reported by Gausman et al. (1977). Some of the denser stands of silverleaf sunflower can be delineated in the NIR band, but it cannot be distinguished in the R band.

Figures 3A, 3B, and 3C show CIR analog video, digital video, and photographic images, respectively, of a peanut (*Arachis hypogaea* L.) field near Pleasanton, Texas. The image resolutions of these images are 2.1 m, 1.3 m, and 0.5 m, respectively. A comparison of the three images shows that the digital video image has better resolution than the analog video image, but does not have as sharp of resolution as the photographic image. Enlargements (10×) (Figs. 3D–F) of the center of each of the three upper respective images further illustrates the difference in resolution. Sparsely vegetated / bare soil areas (white to dull red tones) and the circular tracks of the sprinkler irrigation system are much better delineated in the digital video image than in the analog video image. Although the digital video image does not have as fine of resolution as the photographic image, most of the landscape features can be distinguished in the digital video image.

CONCLUSIONS

The multispectral digital video imaging system described here was designed to provide higher resolution imagery than standard analog (recorded) video imagery. The system provides high quality CIR composite imagery along with its narrowband B&W image components. Image examples demonstrated the value of the multispectral imagery for assessing natural resources. Comparison of the digital video imagery to analog video and photographic imagery showed that the digital imagery had much better resolution than the analog imagery, but it did not have the fine detail of the film. Nonetheless, most landscape features distinguishable in the photographic imagery could also be delineated in the digital video imagery.

The basic digital video system described here can be assembled for about $18,000. The system could be upgraded with the incorporation of both higher resolution cameras and digitizing board, which would provide higher resolution imagery that may approach that of some photographic products, but it would be costly. Replacement of the system described here with a true digital system could result in a threefold increase in cost.

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